Title: Cipher Sleuths

Brief Overview:

This unit immerses fourth, fifth, and sixth grade students into several data analysis activities involving the deciphering of secret codes. Students will analyze the frequency of the letters of the alphabet in a reading passage, graph the data, compare their data to another source, and apply their findings to the solution of several transposition and substitution ciphers. They also will be introduced to vocabulary associated with codes.

NCTM 2000 Principles for School Mathematics:

- **Equity:** *Excellence in mathematics education requires equity - high expectations and strong support for all students.*

- **Curriculum:** *A curriculum is more than a collection of activities: it must be coherent, focused on important mathematics, and well articulated across the grades.*

- **Teaching:** *Effective mathematics teaching requires understanding what students know and need to learn and then challenging and supporting them to learn it well.*

- **Learning:** *Students must learn mathematics with understanding, actively building new knowledge from experience and prior knowledge.*

- **Assessment:** *Assessment should support the learning of important mathematics and furnish useful information to both teachers and students.*

- **Technology:** *Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning.*

Links to NCTM 2000 Standards:

- **Content Standards**

  Number and Operations
  Mathematics instructional programs should foster the development of number and operation sense so that all students understand numbers, ways of representing numbers, relationships among numbers, and number systems; and understand the meaning of operations and how they relate to each other. This unit requires rounding decimals to whole numbers and uses percentages for data comparison.

  Algebra
  Mathematics instructional programs should include attention to patterns, functions, symbols, and models so that all students understand various types of patterns and functional relationships. This unit requires students to recognize patterns of letter frequency occurring in written text. Students must use patterns to construct ciphers.

Data Analysis and Probability
Mathematics instructional programs should include attention to data analysis, statistics, and probability so that all students pose questions and collect, organize, and represent data to answer those questions; interpret data using methods of exploratory data analysis; and develop and evaluate inferences, predictions, and arguments that are based on data. This unit includes data collection and organization and construction of a number line plot to represent their data.

- **Process Standards**

Problem Solving
Mathematics instructional programs should focus on solving problems as part of understanding mathematics so that all students build new mathematical knowledge through their work with problems and monitor and reflect on their mathematical thinking in solving problems.

Communication
Mathematics instructional programs should use communication to foster an understanding of mathematics so that all students organize and consolidate their mathematical thinking to communicate with others; express mathematical ideas coherently and clearly to peers, teachers, and others; extend their mathematical knowledge by considering the thinking and strategies of others; and use the language of mathematics as a precise means of mathematical expression. There are many opportunities to promote discussion and correct use of terminology in this unit.

Connections
Mathematics instructional programs should emphasize connections to foster an understanding of mathematics so that all students recognize and use connections among different mathematical ideas and recognize, use and learn about mathematics in contexts outside of mathematics. This unit connects the use of data collection and ciphers through history and their importance in the world to what students do in the unit.

Representation
Mathematics instructional programs should emphasize mathematical representations to foster an understanding of mathematics so that all students create and use representations to organize, record, and communicate mathematical ideas; and use representations to model and interpret physical, social, and mathematical phenomena.

Grade/Level:

Grades 4-6

Duration/Length:

The unit contains four activities that can be completed in three to five days.

Prerequisite Knowledge:

Students should have working knowledge of the following skills:

- Rounding decimals to the nearest whole number
- Using tally marks in a data table
- Knowledge of the English alphabet

Student Outcomes:

Students will:

- make a line plot from a given set of data.
- decipher a code using deductive reasoning, gathered data, and problem-solving skills.
- learn vocabulary related to codes and ciphers.

Materials/Resources/Printed Materials:

- A textbook or independent reading book for each student
- Brad fasteners
- Scissors
- Student Resource Sheets #1-13
- Teacher Resource Sheets #1-2

Development/Procedures:

Activity 1

1. Introduce the activity by telling students that they will be gathering data that will enable them to "crack" a secret code.
2. Students will work in groups of four for part of the activity, but will also complete some tasks individually. Give each student "Alphabet Stew" (Student Resource #1) to complete independently. They will need a textbook or independent reading book to complete the activity. They should record their data on the Letter Frequency Table (Student Resource #2).
3. When individuals are finished with their tallying, they should then add their totals to the totals of their group members and enter those numbers on their Letter Frequency Table. They will then write a brief paragraph to describe their findings. You may need to caution students that the group data reflects results from 400 letters now instead of just their 100 letters.
4. Lead a class discussion to compare data.

Activity 2

1. Give students the data sheet from NCTM on frequently used letters (<u>Student Resource #3</u>). Point out that the NCTM data is based on a "very large amount of written material" and that the numbers are given as percentages, or out of 100, just like their individual data.
2. Briefly review rounding, if necessary, and have students round each number to the nearest whole number and record it on this sheet.
3. Introduce the concept of the number line plot. Demonstrate using the students' birth month data. (Take a quick survey, if necessary, using a frequency table.) Emphasize that line plots require numbers across the bottom of the graph, not words or letters, so that you would use the number for the months rather than the month name. For the letter frequency data, students will need to use a number value for each letter. For example, A is 1, B is 2, C is 3, etc.
4. Give each student a graphing sheet (<u>Student Resource #4</u>). Have them make a number line plot of the NCTM letter frequency data that they rounded to the nearest whole number in the previous activity.
5. Lead a discussion about their results. Ask them to identify again the five most frequently used letters and the five least frequently used letters.

Activity 3

1. Introduce vocabulary words related to codes (see <u>Teacher Resource #1</u>).
2. Give students Animal Anagrams. (<u>Student Resource #5</u>) Read through the directions with them to be sure that they connect anagrams with the new vocabulary term "transposition cipher". This page can be done as a class, in groups, or individually.
3. Next, give students the Caesar Cipher Chart. (<u>Student Resource #6</u>) Again, emphasize vocabulary terms. You may need to go through the first few letters with them.
4. Students should use the Caesar Cipher Chart to help them solve the Caesar Cipher (<u>Student Resource #7</u>). This can be done in pairs, groups, or individually.
5. Students will now put together a cipher disc to help them make and solve substitution ciphers. Give them the two pages containing the alphabet wheels.
   (<u>Student Resources #8 and #9</u>) They will cut out the wheels and fasten them together with the brads. You may wish to run the alphabet wheels on cardstock to make them sturdier. <u>Please note: The cipher disc only can be used for random substitution ciphers, not for shift ciphers</u>.
6. Have students make up their own substitution cipher using the cipher disc. Use Secret Sleuth Cipher Message (<u>Student Resource #10</u>). This can be done as a class activity or as a homework assignment. When finished, they should exchange messages with a partner to solve the ciphers.

Activity 4

The culminating activity is the Super Cipher Solver Challenge (Student Resources #11 and #12). Students also will need a letter-frequency table to assist them in solving the cipher (Student Resource #13). Directions for the students are on the first page. The directions lead students to determine what the shift of the letters is. The message asks students to write the teacher's name using the cipher and bring it to him/her. This cipher is a letter shift, so the cipher disc will not help students find the solution.

Performance Assessment:

The final cipher activity entitled Super Cipher Solver Challenge can be used as an assessment for this unit. You also may wish to use the message that students make in Activity 3 and the students' solutions to those messages as assessment opportunities. The construction of the line plot from Activity 2 could also be used as an assessment. A scoring rubric has been provided for you (Teacher Resource #2).

## Extension/Follow Up:

Students can make up more challenging ciphers for a partner to solve. The creation and solution of ciphers involving substituting **numbers** for letters can also be explored.

Authors:

Donna Clay
Federalsburg Elementary School
Caroline County, MD

Kathleen Hamilton
Tye River Elementary School
Nelson County, VA

Shanta Church
Graduate Student
UMES
Somerset County, MD
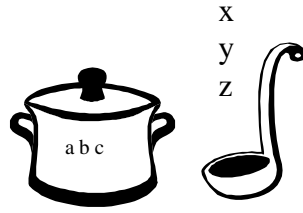
Alphabet Stew

How many letters are in the English alphabet? _____

Name the vowels. _____

Name the consonants. _____

Do you think all of the letters are used with the same frequency? Why or why not?

_____

_____

What five letters do you think are used the most often?

_____

Why did you choose these letters?

_____

_____

Which five letters do you think are used less frequently?

_____

Why did you pick these letters?

_____

_____

Directions: Use a textbook or free reading book and select a page from that book at random. Count off the first 100 letters of any paragraph. Using the Alphabet Tally Sheet put a tally mark next to each letter as you read them left to right. Stop after you have made tally marks for the first 100 letters. Examine your data carefully and answer the questions below.

What five letters had the highest frequency?

_____

What five letters had the lowest frequency?

_____

How did your actual results from your sample compare with your predictions?

_____

_____

Directions: In your group of four people, add the total frequency for each letter and record the number next to your tally marks.

Write a brief paragraph describing the data collected by your group.

_____

_____

_____

_____

_____

_____

_____

_____

Letter Frequency Table

Letter	Tally	My Total	Group Total	Letter	Tally	My Total	Group Total
A				N			
B				O			
C				P			
D				Q			
E				R			
F				S			
G				T			
H				U			
I				V			
J				W			
K				X			
L				Y			
M				Z			

LETTER FREQUENCIES

The National Council of Teachers of Mathematics (NCTM) counted the letters in a very large amount of written material. Their results are expressed as percentages. Remember that percentage means "out of 100". Do your results resemble the ones from NCTM?

Letter	Percentages	Rounded Percentages
A	8.2	
B	1.4	
C	2.8	
D	3.8	
E	13.0	
F	3.0	
G	2.0	
H	5.3	
I	6.5	
J	0.1	
K	0.4	
L	3.4	
M	2.5	
N	7.0	
O	8.0	
P	2.0	
Q	0.1	
R	6.8	
S	6.0	
T	10.5	
U	2.5	
V	0.9	
W	1.5	
X	0.2	
Y	2.0	
Z	0.07	

Source: National Council of Teachers of Mathematics.
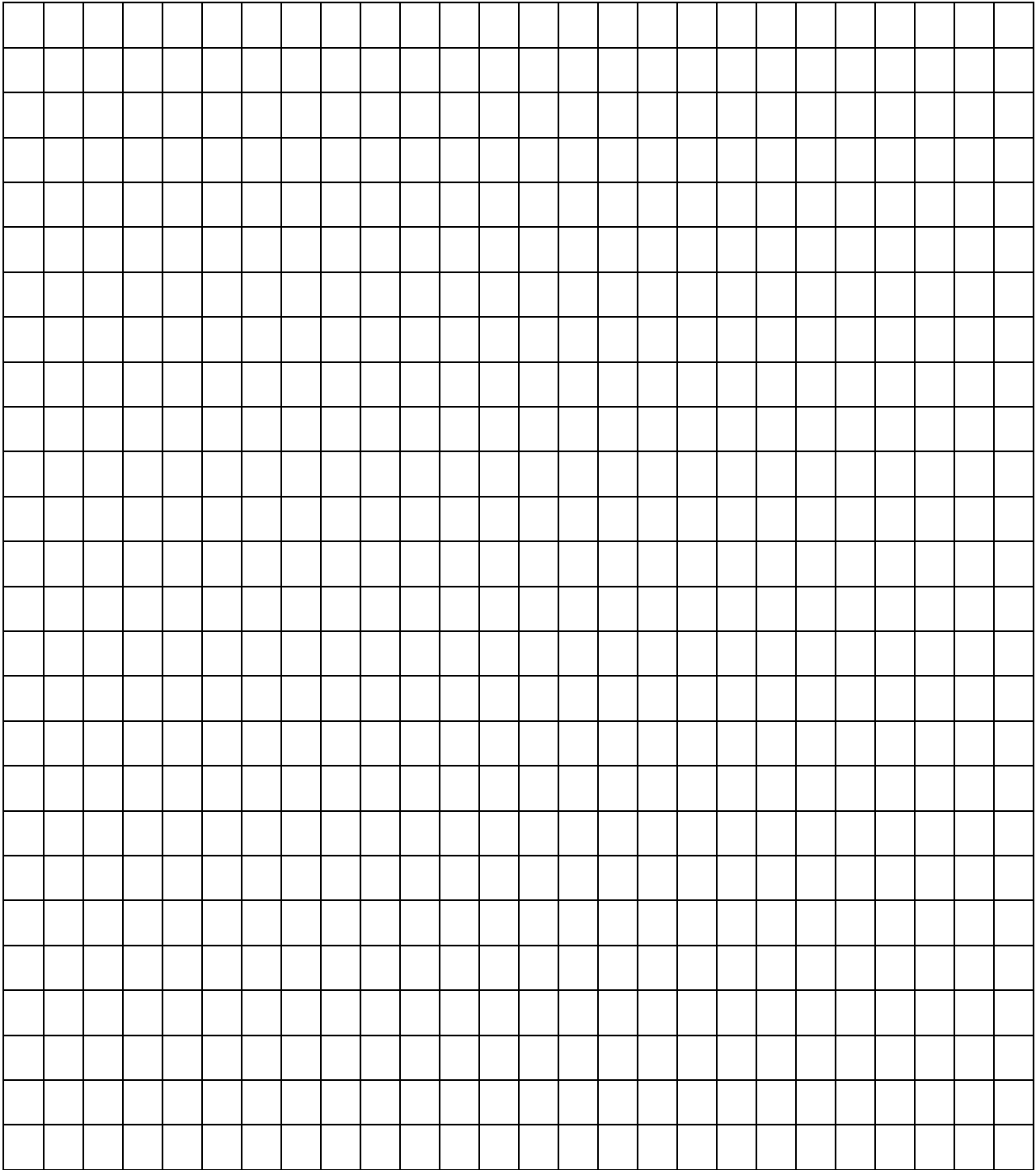
Animal Anagrams

As cryptographers you will work on a **transposition cipher** called an anagram. **Anagram** is a word made by using letters of another word in a different order. Examples of anagrams: **ONE HUG** is an anagram for **ENOUGH**, **SILENT** is an anagram for **LISTEN**

You received the following list in the mail sent to you by a friend in another city. The list was to have been a list of animals but there are no animals on the list. Rearrange the letters in the words to find the name of an animal.

1. **god**

2. **act**

3. **pea**

4. **tab**

5. **tar**

6. **bare**

7. **arm**

8. **flow**

9. **balm**

10. **loin**

11. **looped**

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1. god- dog

2. act- cat

3. pea- ape

4. tab- bat

5. tar- rat

6. bare- bear

7. arm- ram

8. flow- fowl

9. balm- lamb

10. loin- lion

11. looped- poodle

If you want more examples of anagrams there are sites on the Internet. Go

to www.yahooligans.com and type in anagrams.

Caesar Cipher Chart

A substitute cipher is one in which a symbol or letter is substituted for another symbol or letter. Julius Caesar used a simple system of substitution that has his name, the Caesar cipher. The Caesar cipher shifts the alphabet one, two, or three places either forward or backward to create a new alphabet for sending secret messages. For example, if you shift the alphabet one place forward, A would become B and Z would become A. Complete the table below by shifting the alphabet.

Original Letter	Shift 1 place forward	Shift 3 places forward	Shift 1 place backward
A			
B			
C			
D			
E			
F			
G			
H			
I			
J			
K			
L			
M			
N			
O			
P			
Q			
R			
S			
T			
U			
V			
W			
X			
Y			
Z			

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Original Letter	Shift 1 place	Shift 3 places	Shift 1 place in the other direction
A	B	D	Z
B	C	E	A
C	D	F	B
D	E	G	C
E	F	H	D
F	G	I	E
G	H	J	F
H	I	K	G
I	J	L	H
J	K	M	I
K	L	N	J
L	M	O	K
M	N	P	L
N	O	Q	M
O	P	R	N
P	Q	S	O
Q	R	T	P
R	S	U	Q
S	T	V	R
T	U	W	S
U	V	X	T
V	W	Y	U
W	X	Z	V
X	Y	A	W
Y	Z	B	X
Z	A	C	Y

Caesar Cipher

Using the Caesar cipher chart, translate the message written below. First you must

determine how many times (1, 2, or 3) the alphabet was shifted.

Vhqglqj vhfuhw phvvdjhv fdq eh ixq. Wkurxjkrxw klvwrub jryhuqphqwv kdyh

vhqw.

Phvvdjhv lq frghv ru flskhuv. Li hqhplhv lqwhufhswhg wkh phvvdjh wkhb frxog

qrw xqghuvwdqg zkdw zdv ehlqj vdlg.

The alphabet was shifted _____ times.

Write the translation below:

_____

_____

_____

_____

_____

Caesar Cipher

Using the Caesar cipher chart, translate the message written below. You must determine how many times (1, 2, or 3) the alphabet was shifted.

Vhqglqj vhfuhw phvvdjhv fdq eh ixq. Wkurxjkrxw klvwrub jryhuqphqwv kdyh vhqw Phvvdjhv lq frghv ru flskhuv. Li hqhplhv lqwhufhswhg wkh phvvdjh wkhb frxog qrw xqghuvwdqg zkdw zdv ehlqj vdlg

The alphabet was shifted 3 times.

Sending secret messages can be fun. Throughout history, governments have sent messages in codes or ciphers. If enemies intercepted the message they could not understand what was being said.
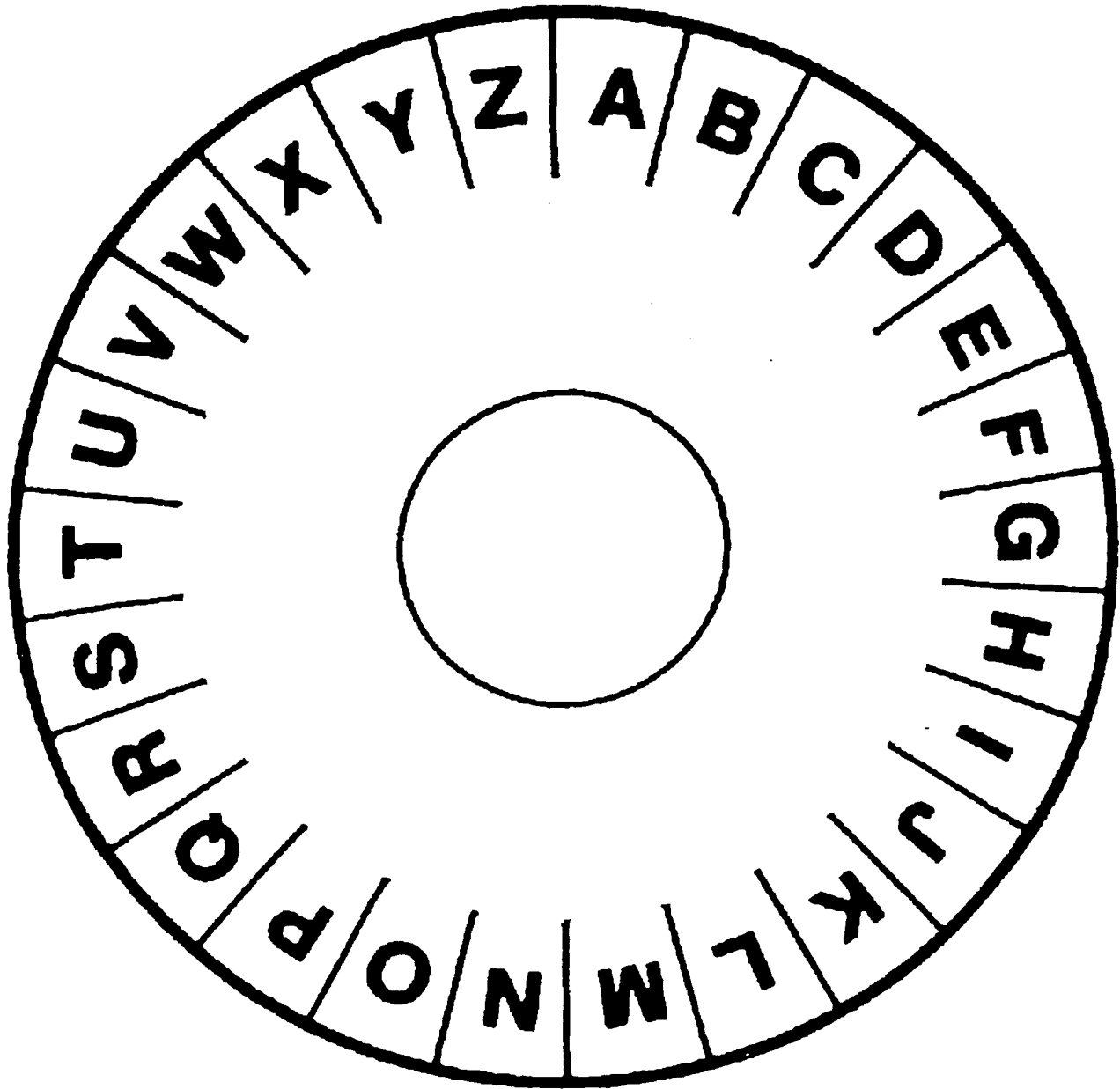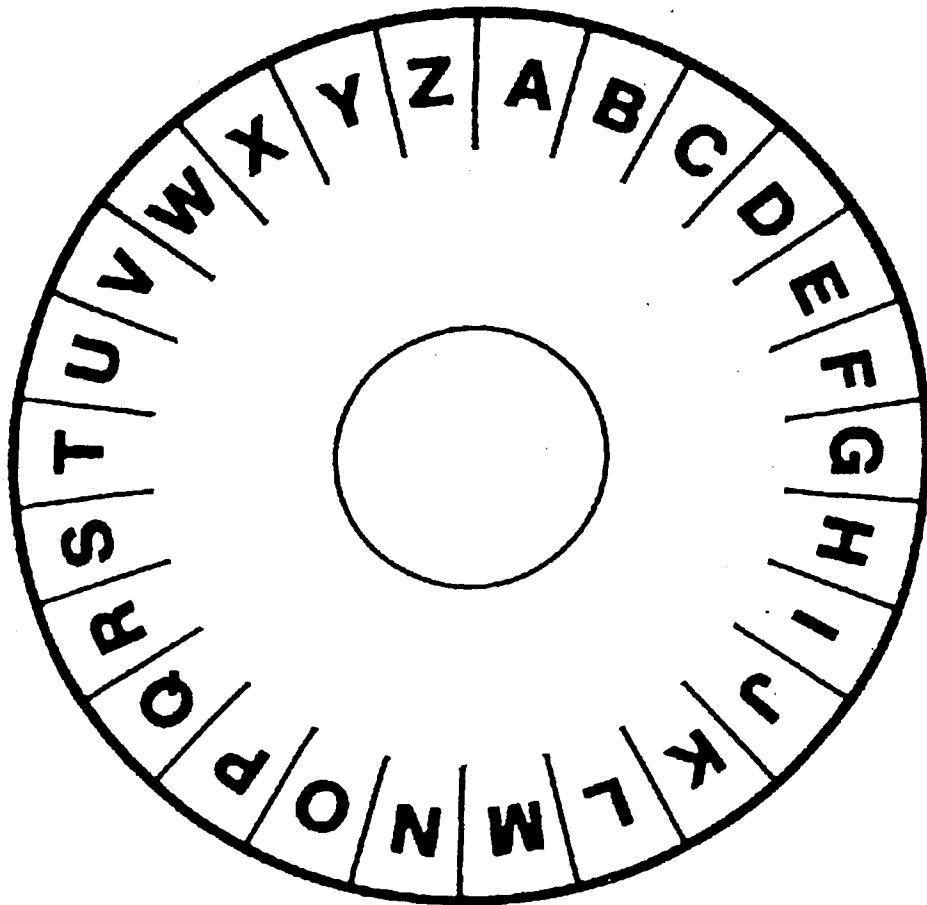
Secret Sleuth Cipher Message

Using your cipher disc write a message to a classmate. The message will be a substitution cipher but does not need to be a Caesar cipher, which means you can shift the alphabet forward or backward as many times as you want. Write the substitution cipher below but keep the real message on notebook paper. Later your classmate will try to translate your cipher.

_____

_____

_____

_____

_____

_____

_____

_____

Super Cipher Solver Challenge

Cryptographers, you have been hired to work at the Super Sleuth Agency. You are given a secret message to decipher. The problem is you do not know if it is a transposition cipher or a substitution cipher. First you must determine which one it is. Cryptographers use a letter-frequency table like the one you used in Alphabet Stew. The table tells you what letters are used the most frequently.
Complete a letter-frequency table using the secret message.

What are the 5 most frequently used letters? _____

What are the 5 least frequently used letters? _____

If your table shows the letters E,T,A,O,N as having high frequency and K,Q,X,J,Z having low frequency, then you probably have a transposition cipher. Remember transposition means the same letters that are in the original message are there, but they are in a different order.

If your table shows the letters E,T,A,O,N as having low frequency and K,Q,X,J,Z having high frequency, then you probably have a substitution cipher. If the cipher is substitution, the shift of the alphabet can be any number of places.

What type of cipher is it, transposition or substitution? _____

Explain how you made your decision, transposition or substitution.
_____
_____
_____
_____
_____
_____
_____

Super Cipher Solver Challenge

Xivvkzexj Jkluvekj,

Kyzj dvjjrxv yrj kvjkvu pfli jcvlkyzex

rszczkzvj.   Tfexirklcrkzfej fe jfcmzex kyzj

jlsjkzklkzfe tzgyvi. Nvcc ufev.

Efn nizkv kyv kvrtyvi'j erdv ze kyv jrdv

tzgyvi reu sizex zk kf kyv kvrtyvi.

SOLUTION:

_____

_____

_____

_____

_____

_____

SUPER CIPHER SOLVER CHALLENGE

Greetings Students,

This message has tested your sleuthing abilities.

Congratulations on solving this substitution cipher. Well

done.

Now write the teacher's name in the same cipher and

bring it to the teacher.

{Note to teacher: Each student should bring his or her

paper to you with your name written in the cipher

correctly.}

Letter-Frequency Table

Letter	Frequency tally marks	Total
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		
K		
L		
M		
N		
O		
P		
Q		
R		
S		
T		
U		
V		
W		
X		
Y		
Z		

New Vocabulary for Cipher Sleuth Unit

Codes- a word or group of letters that stand for another word or group of words.
        The Morse Code is really a cipher not a code.

An example you might want to use is that the Secret Service does not refer to the President or First Lady by their real names when they send a message or talk over the phone or walkie-talkies. For example, the President might be Donald Duck and the First Lady Snow White. The secret service could relate the following message, "Donald Duck is on his way to the ski shop, and Snow White is on her way to school." This message really means The President is on his way to the Senate, and the First Lady is on her way to her office.

Cryptography- science of codes and ciphers.

Cryptanalysis- process of breaking codes or ciphers.

Cipher- each letter in the message stands for another letter.

Substitution cipher- one symbol or letter is substituted for another symbol or letter.

Transposition cipher- the original letters of the message are used but have been transposed or
                rearranged.

An example of this is scrambled words. You might want to give students their spelling words or a vocabulary list that they are familiar with in a scrambled form.

Another example of transposition cipher students might all readily be familiar with are anagrams. **Anagram** is a word made by using letters of another word in a different order. Examples of anagrams: **ONE HUG** is an anagram for **ENOUGH**, **SILENT** is an anagram for **LISTEN.**

Rubric for Number Line Plot

4-   Exemplary
    Main title for the graph
    Horizontal line segment
    Scale of numbers below line segment
    Greatest and least number on the scale must include the range of values in the
        data set
    Number line must include all numbers between the least and greatest value
    Each piece of data in the set represented by an X above the corresponding number
    X's all the same size

3 - Student is missing 1-2 elements of the exemplary line plot

2- Student is missing 3-4 elements of the exemplary line plot

1- Student is missing 4-5 elements of the exemplary line plot

0 – More than 5 elements missing from the exemplary line plot